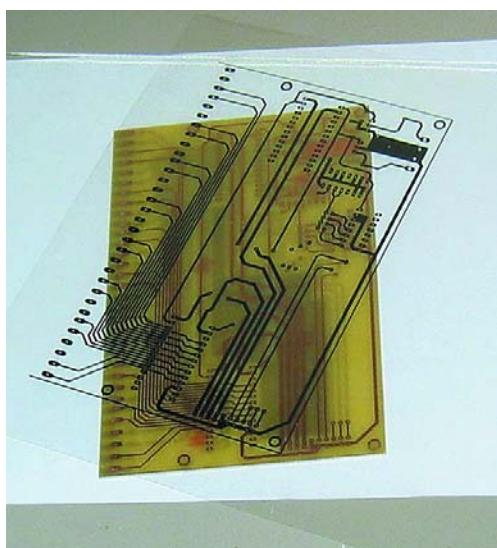


Making Your Own PCBs

tips for circuit board fabrication

By Michael Möge

High-quality PCB layouts for hobby use, small lots or experimental setups can be generated using modern layout programs, some of which are available for free. However, this tidy work on the PC is followed by the unpleasant task of etching the circuit board.



A wide variety of etching kits and accessories are available in electronics speciality shops, but none of them is especially inexpensive and some are rather awkward to use. The difficulties start already with the layout film. Since even expensive overhead projector foils made with photocopiers or laser printers are not sufficiently opaque, it's necessary to superimpose at least two identical foils to expose the board. Copying the layout onto sheet film requires a small but fully equipped photographic darkroom.

Etching using ferric chloride or ammonium persulphate amounts to an exercise in patience and involves hotplates, a lot of mess and accepting a certain percentage of spoiled boards. Disposing of the chemicals is also a problem, and anyone who wants to achieve good etching results and doesn't want to risk

poisoning himself should know what he's about. Chemicals require careful, well-considered handling.

Contact foil

Good-quality opaque foils can be produced using an ink-jet printer. Foils available from Conrad (ink-jet foil OH 3) have proven to be very good. They have a very fine coating, and thanks to the attached backing sheet they are drawn into the printer quite accurately. The foil, with the attached backing sheet, should be placed in the paper feed of the printer (such as an Epson Stylus Color 660 or Canon S450) with particular care being taken to ensure that the glued edge of the foil is positioned fully against the front feed stop and the side edge is tight against the fixed edge guide.

After being printed, the foil should be dried using a hair dryer and then printed again. Two passes through the printer are usually sufficient. It is important to ensure that the printed foil is adequately dried

before being passed through the printer again – a bit of patience is necessary here. If the foil is carefully placed in the feeder, track widths as fine as 0.2 mm can be exactly superimposed in this manner. This yields a printout that is dark black and sufficiently opaque. After being allowed to dry for 24 hours, it can be used to expose the printed circuit board.

Foils from other manufacturers have too coarse a coating, cannot be drawn accurately into the printer due to strong warping or do not have backing sheets.

Exposure and development

An old sun lamp (1000-W mercury vapour lamp) is suitable for exposing the circuit board. The author has obtained good results with an exposure time of just under a minute with the lamp around 50 cm away from the board and pane of glass acting as a cover weight. The optimum exposure time depends on the light source, the type of mask used and

Printer settings

Paper:	photo quality glossy foil (not ink-jet foil!)
Colour:	black
User-defined settings:	fine (720 dpi), no halftone process, -25% brightness, +25% contrast



Figure 1. A suitable overhead foil has a fine surface structure, is free from warping and has a backing sheet.

the quality of the base material. Consequently, before actually making any PCBs you should expose and etch a test board made using a blank piece of circuit board material

exposed in strips.

You can make strip exposures by covering the board with a sheet of cardboard and sliding it a bit to the side every 15 seconds while expos-



Figure 2. The exposure process using a regular sun lamp.

Chat site tips

The following comments have been translated and edited from a 'thread' in the German-language section of a discussion forum at www.batronix.com. The thread contains a useful collection of suggestions and tips for the fabrication of PCBs by electronics hobbyists. The forum and other parts of the batronix website address the complete process of PCB fabrication, from purchasing chemicals to drilling.

Exposure

UV-C from an EPROM eraser is useless! Face tanners (with tubes) are perfectly OK. Use a black underlay, a (double-sided) film (sleeve) resting on two strips of board material and a sheet of glass on top (crystal glass from the glazier is best since it is more transparent to UV), and let the face tanner shine on the board for around two minutes.

Expose our boards using superactinic or UV-A light, which means a wavelength of 400 nm or more. UV-B is never present in professional PCB exposure equipment. You can tell the type of UV from the label on the fluorescent tubes. TL 20 W 05 is good, for example. Six of these per side (120 W) yield a guaranteed mini-

mum exposure time of two minutes for our boards. Type XX yy W 08 or 09 tubes are just as good. The last two digits of the type number (e.g. '05', '08' or '09') give the wavelength. Types 08 and 09 are used in (face) tanners.

To obtain uniform brightness on the board, the distance between tubes should be fairly close to the distance between the tubes and the board, or reflectors should be used. Nitrophot lamps are OK, but they have to warm up first; optimum light yield is obtained only after around 15 minutes. They also have a rather long exposure time for our boards (seven minutes or more). And the longer the basic exposure time, the greater are the deviations from our specification (in absolute terms, 10 percent of 7 minutes is rather different from 10 percent of 2 minutes!). Construction lamps have impressive power ratings, but the heat generated in the mask and board can cause problems.

The advantage of a point source of light is that narrower tracks and track separations are possible. The best point source is the sun, but the weather is a problem. In May, an 5-minute exposure with a heavy glass cover sheet to ensure good contact gives excellent results (and costs almost nothing), but you're out of luck if it's raining or you have to make a board next November.

It's better to expose too long than too short, at least with

good board materials. With a good mask, too long an exposure does no harm. Another good tip is to make a step exposure by removing the protective foil a strip at a time, exposing each strip for X seconds. Strip n that is fully developed after (ideally) 40 s (maximum 60 s), plus one step for the film, gives the (minimum) exposure time = $n \times X$ (make a note of this time, it remains fairly constant).

Development

It's hard to make up for incorrect exposure during development. Bungard boards like a strong developer (13–30 g NaOH per litre), but please keep it at room temperature for safety (a splash in the eye could mean 'lights out' forever).

Store fresh developer in an old plastic container (for large quantities, use the same concentration and keep the container tightly closed, since the solution becomes weak on exposure to air due to the absorption of carbon dioxide). Only take out as much as you need for the job, and rinse it down the drain diluted with water. One-percent NaOH is what comes out of the back of your dishwasher!

If the exposure is too short, a film of incompletely exposed resist will remain on the copper. It sometimes looks like the structure of glass cloth, and during development the colour there will (by design!) turn to something between red-brown and violet. This film prevents the etchant from reaching the copper. As a test, briefly immerse the board in the etchant after it has been developed and rinsed with clear water. The copper in the developed areas of the board must immediately change colour. If it doesn't, the exposure was too short!

One remedy is to rinse the board with tap water, dry it carefully but thoroughly (to protect the exposure device), preferably using (compressed) air, and then expose the entire surface of the board again (the film can hardly be re-applied) for 20 percent of the original time. Develop it again and repeat the etching test. This procedure may sound complicated, but who wants to throw away a valuable board?

The idea is that about 80 percent of the original resist on top of the tracks will be left, which is sufficient for etching, but the thin 'barrier layer' on the rest of the copper will be removed – and the board will be saved!

By the way, our boards can always be exposed multiple times. You can 'misuse' this feature to go as far as creating a sort of solder mask and/or component overlay on the rear of the board. And for those of you who know what 'contrast gain' means, under ideal conditions our boards can be exposed and developed using a photocopy on writing paper, with a suitably short exposure time and a developer that is twice as strong as normal. Other tricks are

also possible.

Etching

Problems in etching come from the exposure, or in rare cases from development. Here I must state very clearly that sodium and ammonium-persulphate are forbidden due to hazardous waste regulations. They etch extremely poorly and decompose if you just look at them (leave alone when you use them), and in terms of achievable track width alone they are catastrophic. The disposal costs are around ten times higher than for ferric chloride. The only reason they are used is because they do not foam (as does ferric chloride), so they can be used in shallow trays.

Etching time: at least 90 s for 35- μm copper with a reasonably fresh solution at 45 °C in a spray-etching machine. Maximum etching time: 180 s, after which the ferric chloride should be replaced; it will then contain at most around five times as much copper as NaPS. In any case, there will be at most 80 percent less hazardous waste exclusively due to the etched copper (but not the etchant itself). Once again, ferric chloride takes up five to ten times more copper per litre than NaPS and allows etching contours down to less than 0.1 mm to be obtained, all in one tenth of the time (using a spray process). It also doesn't eat holes in your clothes, and a spot remover (RX3) help against 'rust' spots.

There is only one etchant that is even more effective, but it is only for pros due to considerations of user safety: copper chloride in the form of a mixture of a lot of water, a little hydrochloric acid and even less hydrogen peroxide. Not for the home user!

Never store a partly used bag open! NaOH attracts atmospheric moisture like a magnet and forms a highly aggressive paste that can lead to loss of sight on contact. You should thus buy developer in special packages for one litre of water, dissolve the contents in a litre of water and keep the liquid in a closed container, or else buy 250-g cans and dole out the contents as needed with a measuring spoon, taking absolutely scrupulous care to keep the container closed.

According to the safety data, pure ferric chloride (granulate or pearls) is less dangerous to life and limb than NaOH. I don't want to over-generalise, but I dare say that an aqueous solution of developer in the intended concentration is fairly harmless (see the dishwasher example). Have you ever carefully read the warnings on dishwasher detergent blocks? Who uses the environmentally friendly developer SENO 4007 instead? And did you know that ferric chloride is used in large amounts to treat drinking water (but of course there's no copper present!)?

Dieter Bungard

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ing the board. After the board has been etched, you can determine which exposure time gives the best results. Due to the UV radiation, you should wear protective glasses (or not look into the light)!

You can easily prepare the development bath yourself. Sodium hydroxide (NaOH) can be obtained from a druggist for a couple of Euros per kilogram. Dissolve 2 g of NaOH in 0.4 l of lukewarm water to make the developing bath. The boards can be developed at room temperature. The photoresist will colour the solution blue-green.

Etching

The best results are still obtained using the tried and true copper chloride process with hydrochloric acid and hydrogen peroxide. Although this process is used for industrial mass production, for home use it is potentially dangerous. When working with acids and alkalis, you must always wear suitable safety goggles.

In this regard, you should also

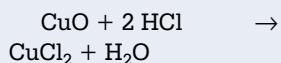
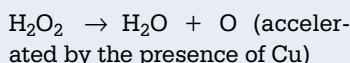
read the comments of 'PCB guru' Dittmar Bungard (see the box).

A solution of 340 ml of 6-percent hydrochloric acid and 160 ml of 15-percent hydrogen peroxide can be used as an etching bath for approximately five Eurocard-sized PCBs. Etching takes around 10–15 minutes at room temperature.

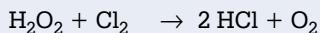
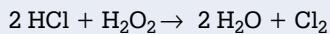
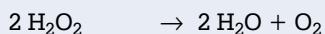
Hydrochloric acid is sold by pharmacists, druggists and in 10-l containers by building supply shops (bricklayers use it to remove calcium

The chemistry in a nutshell

The main reactions are:



The possible secondary reactions are:



residues from walls). Hydrogen peroxide can also be obtained from pharmacists and druggists or from hairdressers.

The board must be rinsed thoroughly under running water between the developing bath and

the etching bath. When the developed board is placed in the etching solution, the areas to be etched away immediately turn red and small bubbles form on the surface of the resist. The board should be moved gently in the etching solution for the full duration of the etching process. Air must not be blown into the solution, since this would cause premature decomposition of the hydrogen peroxide. Heating the bath is neither necessary nor beneficial.

The etching bath will become a light blue-green (from the copper chloride), but no sludge will be formed. If the etching rate drops, the solution can be rejuvenated with a little hydrogen peroxide. If the previously red copper areas turn distinctly whitish, the bath can be salvaged for a certain time by adding some hydrochloric acid.

After etching, the board must again be thoroughly rinsed under running water, but the rinse water must not be simply tipped down the drain. Instead, it must be collected and disposed of properly. The remaining resist can be wiped off using acetic acid ethyl ester (ethyl acetate), universal thinner (fast and cheap), spirit (ethyl alcohol) (some-

what slower) or acetone (very thorough). An even simpler technique is to use a pot scrubber to remove the resist.

The etching process produces copper chloride and water, with oxygen and small amounts of chlorine being released. The primary reaction is the decomposition of hydrogen peroxide. A 'stale' etching solution can be regenerated quite well using 20-percent hydrogen peroxide (H_2O_2) or 20-percent hydrochloric acid (HCl). Higher degrees of dilution yield less satisfactory results. Concentrated chemicals should only be used by qualified experts.

A bath that is still usable can be stored in a loosely capped bottle (since hydrogen peroxide decomposes to form water, releasing oxygen in the process). When the bath is used again, it must be reactivated using hydrogen peroxide.

Disposal

A used etching bath should be allowed to outgas for several days. Hydrogen peroxide breaks down into water and oxygen. The bath will then contain only copper chloride, hydrochloric acid and water. This solution does not form any sludge or flocculent deposits, so it can be readily collected in a plastic container. A mixture of copper chloride and hydrochloric acid can be handed in to any hazardous waste collection depot as pure chemicals. Neutralising the acid with sodium hydroxide (lye) is not recommended, since it can be dangerous. Such a process produces salt water, copper sludge and various gasses. Due to the violence of the reaction, such a disposal procedure should be left to trained chemists.

Although the chemicals described here are used in relatively non-hazardous concentrations, even dilute acids can cause damage. It should be obvious that nobody would drink these solutions. However, for safety you should wear safety goggles and gloves. Splashes on the skin or clothing can easily be washed off or out, but splashes in the eye are a different story. Oxygen and small amounts of chlorine are released during etching. It should be clear that you must not eat, drink or smoke during such work. Suitable ventilation should be provided (opening a window is a good start).

The best results are obtained using Bungard PCB material. Although these boards are more expensive than 'no-name' products, they are worth the money. For very fine features they are indispensable, but boards with coarser features can be made using other products.



Figure 3. Etching equipment.